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OBSERVATIONS UPON THE HABITS, STRUCTURE AND DEVELOPMENT OF AMPHIOXUS LANCEOLATUS.

BY HENRY J. RICE.

PREVIOUS to last season, specimens of that very curious fish-like animal, *Amphioxus lanceolatus* Yarrell, had been discovered along the eastern coast of the United States only in Florida and North Carolina, and one specimen, according to Mr. P. R. Uhler, president of the Maryland Academy of Science, upon the Eastern Shore of Virginia. While engaged in laboratory work at the Chesapeake Zoölogical Laboratory, at Fort Wool, last summer (1878), I was fortunate enough to obtain possession of three adults—two males and a ripe female—and twenty specimens of the young of this very interesting species, thus making Fort Wool not only a new locality for the adult animal, but, so far as I am aware, the only place in America where the young have ever been captured.

Of these specimens the adults were taken with the dredge from the bottom of the bay, south and east of the fort, in a depth of water of from twelve to fifteen feet, and the young were secured by surface dredging with small hand-nets of bolting cloth, from around the wharf, and near the steps of the boat-landing. While they remained alive, which was during the greater part of the months of July and August, I had the opportunity of making a very interesting series of observation, in regard to their habits, and those peculiarities of structure and development which have drawn so much attention to this animal, and rank it as at least the lowest of vertebrates, if not an intermediate type between Vertebrata and Invertebrata. These investigations, the results of which

I have embodied in the following necessarily incomplete summary of our present knowledge of Amphioxus, were conducted with a great deal of care, and while they have led me to differ from the commonly received views in regard to certain particulars of structure and development, they have enabled me, by a somewhat detailed comparison of results, to corroborate much of what has already been done in this important field of research.

History.—This apparently insignificant little creature was first made known to science, in the year 1778, from specimens found upon the coast of Cornwall, England, and sent to Peter Simon Pallas, a celebrated German naturalist, who was then issuing his Record of new forms of animal life. The description given in this Record[1] is, in the main, quite accurate, but from some misunderstanding of the nature of the ventral ridges, or perhaps from some slight resemblance to a sea-slug, Pallas considered it a new species of snail, and named it *Limax lanceolatus.* Had he had the opportunity of examining other than contracted specimens of this new form, he probably would not have written, "Tentacles evidently none," and might have hesitated before placing it among the Limacidæ. But if Pallas failed to correctly estimate its generic features, the next writer who mentions it[2] seems to have been able to appreciate them to a certain extent, for he remarks, that it is "hardly a Limax," although for some reason he retained this name, and adds to it, probably through some typographical error the specific term of *lanceolaris*, which ought only to accompany the genitive of Limax, or Limacis. After this notice by Stewart, *Limax lanceolatus* seems to have dropped from the vocabulary of zoölogists and to have passed almost from the memory of those engaged in describing and classifying new species of animals, for in 1834, when Costa[3] discovered this same animal in the Bay of Naples, Italy, he failed to recognize it as having been described before, and considering it a new species of fish, he named it *Branchiostoma lubricum*, from the fact of its having tentacles about the mouth, and upon the supposition that these tentacles subserved the purposes of respiration as branchiæ.

[1] Spicilegia Zoölogica. Peter Simon Pallas. Fasc. x, p. 19. Taf. 1, Fig. 11. Berlin, 1778.

[2] Elements of Natural History. —— Stewart. 2d edition. Vol. 1, p. 386.

[3] Cenni Zoölogici ossia descrizione sommaria di talune specie nuove di animali. O. G. Costa. Page 49. Napoli, 1834. And, Storia el *Branchiostoma lubricum.* Napoli, 1843.

Almost simultaneously with this discovery of Costa, it was rediscovered upon the coast of Cornwall by Mr. Couch, and was recognized by Mr. Yarrell as the *Limax lanceolatus* of Pallas. But Mr. Yarrell also recognized as Costa had already done, and thus corroborating the doubts of Stewart, that instead of being a Limax it was, in reality, closely allied to the class of fishes, and not aware of its discovery in Italy, by Costa, he erected a new genus for it, *Amphioxus* (*Amphi*, on both sides, and *oxus*, sharp, from the fact that both extremities are pointed), and described it in 1836[1] as *Amphioxus lanceolatus*. It will thus be seen that the generic name assigned it by Costa has priority over that instituted by Yarrell, but the term Branchiostoma being founded upon a misconception of the functions of the tentacles, and the specific name of Pallas having priority over all, the name as given by Yarrell, *Amphioxus lanceolatus*, has come, by common consent, to be adopted as the appellation of this small denizen of the sea. Since 1836 Amphioxus has been found inhabiting nearly every quarter of the globe, specimens having been taken in China, Borneo, South as well as North America, and along the entire coast of Europe, although it has been found most abundantly in the waters of the Mediterranean sea, near Naples and Messina, Italy, where at present the conditions seem to be most favorable for its propagation and growth.

These various specimens, coming from such widely separated localities, were supposed, by their discoverers, to represent distinct species of this animal, and specific names have accordingly been given them, as *Amphioxus belcheri* Gray, for the East Indian form, and *Branchiostoma caribæum* Sundeval, for the form upon our coast, but the best informed European systematists consider that all these forms represent but a single species,[2] the *A. lanceolatus* Yarr., of Europe, which thus becomes one of the most widely distributed, as it is certainly one of the most anomalous of existing animals.[3]

[1] Hist. of Brit. Fishes. Wm. Yarrell. Vol. II, p. 468. London, 1836.

[2] Traité de Zoölogie. Page 808. Paris, 1878. Translated by Prof. G. Moquin-Tandon from the third and latest edition of the Handbuch der Zoölogie of Prof. C. Claus.

[3] Dr. Gill, of the Smithsonian Institution, informs me that Sundeval separated the Caribæan form from that of Europe on account of a difference in the number of plates, or fibers in the muscle-plates, of one form from that of the other. I have not as yet been able to examine the two forms with a view to determine this point.

General Description and Habits.—The adult Amphioxus, Fig. 1, Pl. 1, is a small, rather slender animal, which lives for the greater part of the time entirely buried in the sand along the sandy portions of the shores which it inhabits. When fully grown it is about two inches in extreme length, rarely somewhat longer, and of a pale flesh color which changes, when seen by reflected light, to a beautiful display of metallic iridescence.

Its body is smooth, very muscular, much compressed from side to side, and tapers gradually to the extremities, which are pointed, but differ considerably in contour, for while the posterior is lance-shaped, from whence is derived the specific name of *lanceolatus*, the anterior is formed like the ram of a modern gun-boat, and is admirably well adapted for forcing a way through the sand in which it burrows. The abdominal portion of this blade-like structure forms a dilatable sack which extends from near the anterior end of the body back for about two-thirds the entire length of the animal, where it terminates in an opening, the abdominal pore or branchiopore, which places the cavity enclosed by the sack in communication with the exterior. During the life of the animal this abdominal sack is seen dilating and contracting quite regularly, although at rather lengthy intervals, with a wave-like motion which begins at the forward end of the cavity and travels backward, rather slowly, to the posterior extremity. When the sack is completely distended this portion of the body presents a full, clear, rounded appearance, and projects considerably below the ordinary ventral outline, but when contracted, as it is in all preserved specimens, all appearances of a cavity disappear, leaving merely a slight indentation where the "pore" is situated, between the abdominal and the tail portions.

Through the center of the muscular part of the body, and forming an axial support to the animal, there is a long, slender, semi-cartilaginous rod, which is pointed at each end, and which extends from the very point of one extremity to that of the other. This rod is composed of an external membraneous sheath enclosing a series of closely approximated flattened disk-like bodies, and is probably the homologue of the vertebrate notochord, or backbone, although not exhibiting any anterior cranial expansion. Above it, but not extending quite as far forward, is the main nervous system, or chorda dorsalis, and below it lies the long, nearly straight alimentary canal. This canal opens anteriorly by a longitudinal

aperture, the mouth, placed upon the median, ventral line just behind the depressed ram-like termination of the body, and between it and the anterior portion of the abdominal cavity. This oral opening is of moderate size, and is surrounded by about thirty-one tentacles which are moderately long and slender, and bear upon their sides little protuberances which give them a toothed appearance. The anus, or outlet of the canal, is funnel-shaped, and opens very eccentrically upon the left side of the body just beneath the level of the notochord and *quite* near the end of the tail. The left or free edge of this aperture does not extend at its posterior limits quite down to the ventral edge of the muscle-plates, so that the anus also opens, to a certain extent, *towards* the left side of the body, although the fœces are expelled directly backwards and downwards along the side of the median fin. This free edge is quite flexible and in hardened specimens is so contracted, together with the surrounding parts, that the anal aperture appears to open into a pseudo-cloaca. The integument, which forms the greater part of the mouth tentacles, is thin and nearly transparent, and expands along the entire length of the dorsum, and around the tail, and as far forward as the branchiopore, into a delicate, median fin of nearly uniform width except upon the edges near the posterior extremity, where two unequal lobes are formed which represent the blades of this "lance" termination. Of these two "blades" the ventral is the larger, and its posterior curvature is nearly below the anal opening of the intestine. The integument also forms two longitudinal folds, which extend along either side of the abdomen, from the posterior portion of the mouth orifice where they originate, to the indentation which exists between the abdominal and the tail portions. Here, after forming a sort of triangular pit into which the branchiopore opens, they become merged into the median, ventral fin, which, as already stated, reaches forward to this point. When the abdomen is fully extended these folds become nearly obliterated, and are barely visible as lines running along the sides parallel to and at some distance above the ventral outline; but when the abdomen is strongly contracted they form prominent ridges along the lower edge of the body, and so change the appearance of the specimen that it is not much to be wondered at that Pallas should say, that this portion looked "very much like the very narrow foot of a snail."

These folds are hollow and have been thought, until quite recently, to have an opening at either extremity, but Prof. Ray Lankester denies[1] that there are any such openings, and I have failed to obtain any evidence from my specimens that any such apertures exist. With the exception of these side-folds and the mouth tentacles, the integument presents no appendages whatsoever. External sense-organs are also wanting, except upon the left side of the body near the anterior end of the chorda dorsalis, where a small ciliated pit is said to be located which it is claimed, by Kölliker,[2] its discoverer, and others, represents a nasal depression, or cavity. I have not been able to make out this pit, and even if it is present, it is probable, that these animals gain their impressions of external objects entirely by the general sense of touch.

The adults, while varying somewhat in size, as is the case with most adult animals, do not differ very much otherwise in general appearance except during the breeding season, when the female becomes filled with ova, and the abdominal portion becomes, in consequence, much larger than ordinary. At this period the ova show very plainly as a row of large white spots along either side of the animal, Fig. 1, Pl. 1, but at other times, and in the males, there are no such spots visible to the naked eye. These differences of size and sexual appearance were well marked in my specimens, for while they varied in length from $1\frac{1}{16}$th to $1\frac{7}{16}$th inches, thus being of rather small size, the female, which was the largest, was so distended with ova that her body was much rounder, and consequently more opaque in appearance than the bodies of the thinner males. The young, Fig. 5, Pl. 1, and Fig. 7, Pl. 11, resemble the adults very much in outline, but differ in many points of structure, which will be noticed in treating of their development, and in being quite transparent, looking much like animated bits of isinglass when in the water. This transparency, however, gradually gives place, as they grow old, to a semi-opaque condition which permits the outline of different parts to be made out, but not with any great degree of distinctness unless under a very strong light, and the older and larger the specimen, as a matter of course, the less the distinctness. The young specimens varied in length from $\frac{5}{64}$th to $\frac{5}{16}$th of an inch, although the greater number were about $\frac{2}{16}$th of an inch long.

[1] On some new points in the structure of Amphioxus. Prof. E. Ray Lankester. Quar. Jour. of Micro. Science. Vol. 15, p. 257, 1875.

[2] Müller's Arkiv, p. 32. Berlin, 1843.

All of the above-mentioned specimens which came into my possession, were gathered together during the period from the 9th of July, when the first specimen, an adult, was obtained, to the 2d or 3d of August, after which date no more could be found. The young were taken mostly at night, one or more at a time, when the water was comparatively quiet, but the greatest number captured on any one occasion was at noon of a very hot day, when there was scarcely a breath of wind, and the surface of the bay was almost as smooth as the proverbial "sheet of glass;" these small inhabitants thus seeming to be affected by heat, and especially by a quiet condition of the water, in very much such a manner as are the myriads of other young animals which are floated hither and thither by the currents of the sea at this season of the year. As soon as taken they were transferred to tumblers which had been previously filled with fresh sea-water, and each tumbler was generally occupied by four or five specimens. The water was changed daily in all the vessels. When first placed in these receptacles they darted about with a quick "wiggling" motion which resembled somewhat the movement of a tadpole, but different in that the head, or anterior part of the body, moved from side to side as far and as vigorously as the tail portion. This peculiar undulation was generally kept up for some little time at or near the surface, when suddenly they would cease all motion and allow themselves to sink slowly to the bottom, where they would remain flat upon their sides until again impelled to action. When this impulse came, from whatever cause, and they were once started from their resting place at the bottom, they generally swam directly upward to the surface, moved about here for a short time, and then, as before, suddenly stopped and allowed themselves to sink again to the bottom. But sometimes one of the inhabitants of a dish would start up, seemingly impelled by some willful freak, dash about close over the bottom and stir up all the others in the vessel, when there would be, for a moment or so, quite a brilliant display of undulating, flashing forms.

The largest of these young specimens was pretty well advanced in development, and was placed in a separate dish which had a layer of sand upon the bottom. It was thus isolated for the purpose of ascertaining if it would make use of the sand as a place of refuge, but only on one or two occasions, and then for very

brief periods, did it ever disappear beneath the surface. Generally it lay flat upon the top of the sand, until disturbed from its repose, when its actions closely resembled those of its smaller fellows. Hence it must be at a later period of life than that to which this one had attained, that these little animals cease to be shifted about by the flood and ebb of changing currents, and become "burrowers." The adults, which were taken from the banks by means of the dredge, were placed together in a large jar of sea-water, which was furnished, like the dish of the largest of the young animals, with a layer of sand upon the bottom. When once in the water they commenced swimming about very rapidly, with the same graceful, undulating motion which has been noticed as characteristic of the young, but with much greater vigor and elasticity. These movements were executed sometimes upon the back, sometimes upon the abdomen in the position of ordinary fishes, it seemed to make very little difference which side was uppermost, but I have never seen them move backwards, or tail-end foremost. After circumnavigating the vessel once or twice, gradually moving slower and slower, they would stop and sink down upon the sand at the bottom. Generally as soon as they touched the sand they would half-arch their bodies and almost instantaneously disappear from sight beneath the surface, thus regaining their natural place of refuge. After this disappearance they very rarely entirely emerged from their retreat, and as a rule, not at all during the day time. But if the surface of the sand was carefully examined at night, little spots might be detected where the sand appeared less compact than elsewhere, and a close inspection would discover each such spot to be a network of crossing tentacles arching over the expanded mouth cavity of one of these animals, which was thus, while lying belly upwards buried in the sand with only its mouth exposed at the surface, busily engaged in drawing its food from the water above.

Sometimes they could be found so situated during the day time, and now and then both by day and night, but rarely in the day time, one or more of them could be seen protruding part way from the sand, and looking as if planted in this position, but a tap or a motion of the vessel would cause them to withdraw from sight immediately.

These actions would seem to indicate what is probably a fact,

that the day time is to these animals a period of rest, when they remain entirely buried beneath the surface, and night time a period of activity, when they come up to feed and perhaps to move from place to place, as they have been seen swimming about during the night in the aquarium at the Zoölogical Station at Naples, and on one or two occasions I have found, early in the morning, one of my specimens lying entirely out of the sand, fully exposed to view, and in all probability it had been swimming about during the night.

On account of the propensity of these animals to remain concealed from sight it was necessary, whenever they were wanted for examination, to drive them from the sand, and this was by no means an easy task, as they are such exceedingly active little beasts that they would work their way from side to side of the dish beneath the sand, very nearly as quickly as I could run a stick or pencil through it in trying to find their position. And when once forced out, they would dart through the water so impetuously, and plunge into the sand again so quickly that their movement seemed merely a flash in the water, and a few particles of floating sand and mud would alone indicate that one of them had been out of their proper domain. Generally this chasing process had to be repeated four or five times, when they would become exhausted, and after undulating about the jar very slowly for a moment or so, they would sink upon the sand and remain perfectly quiet, flat upon their sides, for sometimes half a day at a time. During these intervals they could be transferred from dish to dish and even placed under a low power of the microscope for examination. But if not completely exhausted a short rest would revive them, and then, when touched, they would dash away as impetuously as ever, and I have had them, on such occasions, rush out of the water and over the broad rim of a large plate on to the table, and before they could be touched, much less secured, throw themselves off the table and down upon the floor. But the adults appear to be so vigorous that these falls, which occurred on two different occasions, did not seem to have the least injurious effect. As may be surmised from this, all their movements are exceedingly quick, and this rapidity in going through sand and water, and hence the ease with which they can move about from place to place, is probably the reason why we secured only three of these animals at Fort Wool.

We made a large number of dredgings but the dredge used was too coarse and heavy for such work, and as we had had no idea of finding Amphioxus at this place, we were unprovided with one of suitable construction. It is probable that with a proper dredge, perhaps a ring dredge, made light and with fine meshes, they could be taken in this locality in fair numbers, and it is possible that places might be found along our coast, if searched for, where they could be taken in as great abundance as at Naples and Messina, in Italy. And where the adults are found the young could be taken also, if looked for during the breeding season, which in this country is probably during the months of June and July. I base this statement upon the facts that my young specimens, which were somewhat advanced in development, were taken mostly during the second and third weeks of July, and that only one specimen could be secured after the close of that month. Amphioxus does not appear to be a difficult animal to keep if supplied with plenty of sand in which to burrow, and a daily change of water of a density equal to that which is found at the place of its capture, My adults remained alive and appeared to be in fine condition as long as I could give them water which came in fresh from the sea every day, but in September they were carried up the bay to Tangier's sound, where being unable to supply them with suitable water they soon showed unmistakable signs of debility, and on the 10th inst. they were placed in picric acid to be ready for future service. None of the young remained alive as long as did the adults, and only a few grew so well and appeared so vigorous as to indicate that they would reach maturity. Some of them, from some cause, became dwarfed and drawn out of shape so as to look, in one or two cases, like a large letter S, and others, probably from the erosive or wearing action of bits of sand, or something of the kind, which had entered the stomach and intestines along with the food, had lost portions, and sometimes half of their bodies, and yet these little deformed and maimed animals lived sometimes for a week in such condition, evincing certainly a good degree of vitality, and enabling us, if Amphioxus is really one of the earliest of animals, the better to appreciate the "why and the wherefore" of the persistence of this species to present time.

The Skeleton.—The framework of Amphioxus is entirely cartilaginous, and is composed of the notochord; a series of processes

said to represent spinous processes, which extend along nearly the entire length of the dorsum, and along the ventral side of the tail portion of the animal; and a series of arches or supports which are formed along and in the sides of the anterior half of the alimentary canal. The *notochord* has already been described, and its position defined as forming an axial support extending from end to end of the body, and representing the back bone of higher vertebrates, but lacking the anterior expansion or brain case. The *spinous processes* form rows of semi-transparent, perpendicularly placed, block-like bodies; the dorsal row originating over the chorda dorsalis, and rising upwards from between the side muscles to form a median basal support to the dorsal fin; and the ventral row originating beneath the intestine and extending out from between the side-muscles to form a support to that portion of the median fin which extends from the branchiopore back to the ventral "blade" of the tail. These blocks are well marked, and form quite a prominent border to the greater part of the outline of the muscular portion of the body. (Figs. 1 and 5, Pl. 1, and Fig. 7, Pl. 11.) The series of bodies pertaining to the alimentary canal consist of a mouth ring, a pharyngeal ring and a variable number of rib-like arches placed alternately upon either side of the canal and extending back to about the middle of the body. These different parts are unconnected above, unless it may be to a slight extent with the sheath of the notochord, but below, the two rings, which arise from a common base, are connected with the arches by a cartilaginous trough-like formation which extends back as far as the last arch, and in the sides of which the bases of the arches are firmly imbedded. The *mouth ring* is formed in the integument of the edges of the mouth orifice, and arches forward and upward in conformity to the outline of this portion of the body. It is made up of segments, one for each tentacle, and each segment sends out from the side, at the anterior end, a long, slender prolongation which extends, as a central support, to the very tip of its corresponding tentacle. (Fig. 2, Pl. 1.) These segments, which are the same in number upon both sides of the mouth, do not unite in front, but form arms which end upon either side just at the base of the ram-like extremity of the body, and at these terminations of the "ring" new segments are formed, when, in the growth of the animal, there is room in the oral circlet for additional tentacles.

The odd tentacle which is found in the mouth circlet of Amphioxus, is formed from the center of the basal portion of cartilage from which the two rings originate. The cartilaginous portions of all these tentacles are curved inward, and so directed that the tentacles in the normal condition always cross each other, much as the fingers of a person's hands can be interlaced, and thus form a rude sieve which prevents the entrance of large substances into the digestive tract. The *pharyngeal ring* which marks off the anterior limits of the abdominal cavity, forms a sort of welt or slight constriction around the inside of the anterior portion of the alimentary canal. It is curved backwards upon both sides, and bears upon the posterior border of each curved portion two or three rather large fleshy-looking tentacles. (Fig. 2, Pl. 1.) These tentacles generally lie directed backwards against the side walls of the digestive tract, but they can be brought forward so as to extend directly across the canal and form a second barrier to the onward progress of large bodies. In the young this barrier is of much greater service in preventing entrance to the digestive tract than the oral tentacles, as these latter appendages are not sufficiently numerous to act as an efficient guard until the animal is of considerable size, as large or larger than the largest of my young specimens. These tentacles are not always of the same size, and are generally so placed upon the sides that when brought forward they alternate one above the other.

The *branchial arches* are frame-like in structure, long and slender in outline, and run obliquely downwards and backwards across the entire width of the canal—this obliquity is such that the center of the upper portion of one arch is about over the center of the lower part of the next arch in front. The arches are quite numerous, fifty, more or less, upon each side, but I am not aware that there is any definite limit to their number, the largest individual appearing to have the most arches. The greater number of them are of uniform length, but as they approach their posterior limits they gradually become shorter and shorter, to the last one or two, which are less than a quarter the length of the longest ones. The first and second arches are also much shorter than the others, and are about the length of the last ones. The first and last arches are very simple in formation. The first is composed of an oblong framework, pointed at the lower end and nearly square or somewhat pointed at the upper. It is about

twice as long as broad, almost upright in position, and is placed just posterior to the lower curvature of the pharyngeal ring. The last one is merely a round or nearly round ring of cartilage. The rest of the arches are shaped much like the first, but are bi-lobed above and have a central bar which passes from the indentation of the bi-lobed end down to the cartilaginous bed which encloses the pointed lower extremity. This bar is about twice as wide as either side of the arch, and is marked throughout its entire length by a median line which indicates a division into two slender halves. In all of the longer arches there are also three cross-bars, which pass from side to side of the arch at about equal distances between the two ends, and in the shorter arches, except the first and last, which contain none, there are sometimes one, sometimes two of these bars in each arch. These bars pass obliquely backwards and upwards across the arch, and generally go directly from one side to the other, but some of them divide at the central bar and become attached to it, so that they form two short bars instead of one long one. The arches of each side are placed close together, edge to edge, so that they have the appearance of a connected, continuous series of long slender oblique bars, each marked by a median division line and separated by a space of about the same width as the bars themselves, and with cross-bars running, with more or less regularity, across these spaces from alternate bars. The upper edge presents a series of uniform lobes, and the lower edge a series of larger uniform arched points, there being left between each two points a triangular space of considerable size. (Fig. 4, Pl. 1, *a*.) Each complete arch is thus made up of two nearly similar halves, and as the arches of the two sides alternate with each other, as has already been said, the triangular spaces at the bases of the arches not only serve to show the divisions between them, but also indicate the positions of the opposite arches. This alternation can be readily seen by placing an adult animal, when living, under a low power of the microscope, or by a careful dissection of this portion of the body.

The Digestive Tract.—The alimentary canal, which extends along beneath nearly the entire length of the notochord, is somewhat compressed from side to side, varies considerably in breadth in different parts, and is lined throught its entire length with cilia which serve by their action to draw food into the canal for the

nourishment of the animal. The canal may be divided into five rather natural divisions; the mouth cavity, extending from the mouth orifice to the pharyngeal ring; the pharynx, the œsophagus and the stomach, extending from the pharyngeal ring to the division between the abdomen and tail, and which hang from their attachment beneath the notochord freely suspended in the abdominal cavity, being completely enclosed by its walls; and the intestine, which extends along through the tail portion of the animal to the anus, near the posterior extremity. The *mouth cavity*, or first division of the canal, is somewhat triangular in shape, being circumscribed above by the notochord, and below and behind by the two orifices already mentioned. Its anterior upper outline is curved, and it bears upon its walls certain slight, finger-like ridges where the cilia of this cavity are principally aggregated.

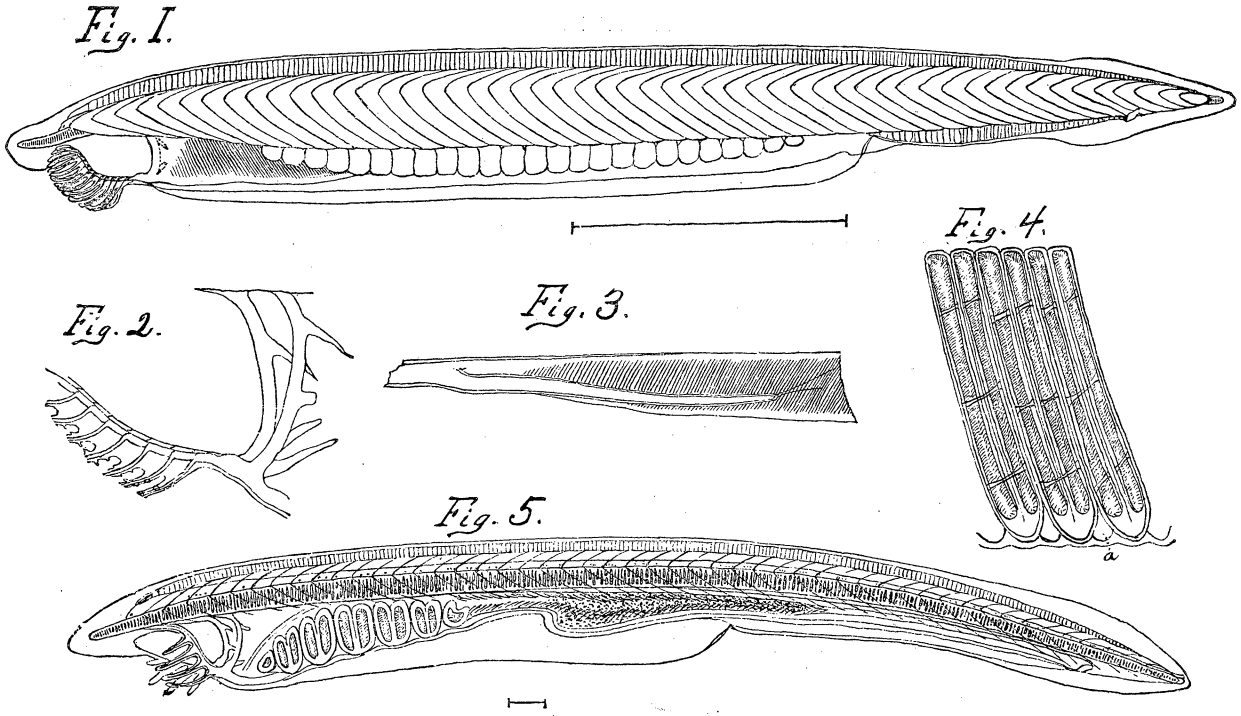
At the rather constricted opening of the pharyngeal ring it merges into the *pharynx*, which extends a little past the middle of the abdominal cavity, and is the largest division of the canal. This portion is that in which the branchial arches are formed, and has much the shape of a bean pod, being quite broad along the central part and narrower towards each end, but the posterior extremity tapers much more gradually than the anterior, and where it merges into the œsophagus, it is hardly more than half the size of the portion at the pharyngeal ring. Along its sides, in all the spaces between the bars of the branchial arches, there are long narrow openings, called branchial slits, which place the interior of the pharynx in communication with the abdominal cavity, which is also known as the branchial cavity, or atrium, but which might more properly, perhaps, as will be noted later on, be called the *branchium*. These branchial slits extend, with few exceptions, from the upper curves down through nearly the entire length of the arches, to the edges of the cartilaginous, trough-like bed, being crossed here and there by the cross-bars which serve to stiffen the general framework. In the first two or three arches the clefts do not extend quite to the upper borders. Along the inner edges of these slits the cilia of the pharynx are very long and arranged in rows completely encircling each slit (Fig. 4, Pl. 1), so that by their action they intercept the food particles which are brought into the canal and which might pass through the slits and drive them onward towards the stomach, but allow

the greater portion of the water, in which the food is brought into the canal, to escape into the branchium and be forced, by the contraction of the walls of this cavity, out through the branchiopore once more into the surrounding medium. The *œsophagus* is a short narrow portion of the canal, and leads from the pharynx directly into the *stomach*, which enlarges considerably in diameter, and extends straight back to the end of the branchium. Its walls are rather thicker than those of the other portions of the canal, and upon the inside the cilia are disposed in such a manner that when in motion they force the particles of food, which come into the receptacle, into a long rope-like body, and then cause this food-rope to revolve and twist about until all the nutriment and shape is twisted out of the component particles and the refuse material is forced on into the intestine. The food consists of diatoms, algæ and most any bit of organic material, plant or animal, which is floating in the water in the neighborhood of the animals, and which can succeed in passing the guards and entering the stomach, and if a young animal is taken and placed in some water under the microscope, the entrance of these particles into the canal and their gradual grinding up as they get into this vortex of the stomach, can be readily seen through the nearly transparent tissue, and well repays a little time spent in such observations. Ordinarily these little bits—animals or plants—sail along down the canal without any hindrance from the guards, and as they approach the end of the "rope," they commence rotating slowly about the sides, often, in the case of animals, making uncertain efforts to escape, until after rolling around for a time they are gradually pressed into the mass and twisted on to make room for the others which are continually floating in from the outside. Sometimes a long piece of an alga, or partially decayed bit of organic material, is drawn by the powerful action of the cilia, with a quick rush, against the mouth orifice or into the mouth cavity; then, with a motion which seems nearly instantaneous, the pharyngeal tentacles are brought forward with a sudden flap, the mouth aperture is widely distended, and the offending substance is thrown out of the body together with the water which was in the mouth cavity, after which the tentacles return to their normal position along the sides of the pharynx. This action is often repeated four or five times before the object is gotten rid of, as the action of the cilia tends to

draw the substance back again immediately into the mouth, and at times, after all this labor to get rid of a substance, it finally succeeds in eluding the tentacles, which flag in their activity after a few efforts, and passes on down the canal. From the lower anterior portion of the stomach there is given off a long, slender saccular diverticulum which extends forward along the lower portion of the right side of the pharynx to about the middle of this part of the body, where it is attached by one or two bands to the bars of the branchial arches, and perhaps to the side muscles, Fig. 3, Pl. I. This organ is considered to represent the liver. It is of a dark-green or brown color, which is probably due to pigment cells in its walls. The walls of the stomach are also colored, but not so deeply as those of this saccular liver. All this portion of the alimentary canal, including the pharynx, œsophagus and stomach, is covered with a delicate membrane which is reflected from the inside of the abdominal walls, and forms along the roof of the branchium, on either side of the canal, a true pleuro-peritoneal cavity, or schizocœle, which extends back quite to the end of the digestive tract. The *intestine* forms the posterior portion of the alimentary canal, and passes in a perfectly direct course from the stomach to the hind end of the body. It is much smaller than any other portion of the canal, and is of uniform diameter except at the posterior extremity where it enlarges to form the funnel-shaped outlet of the anus. It is not known at present time whether the cilia along the course of the alimentary canal are continuously at work drawing in food, or whether they have periods of rest during which they are perfectly quiet. I have never seen them quiet except upon small patches and in weak animals, and then not for any great length of time, but the fact that the stomach and intestine are very frequently found devoid of food, or of all but a small amount of excrement, would seem to indicate that these animals are not always feeding, and this would imply that they can control, in some manner, the action of the cilia. This would accord well with their habits, and would corroborate to a certain extent the statement already made, that they probably have feeding periods, during which they appear at or near the surface, and resting spells, when they hide from sight.

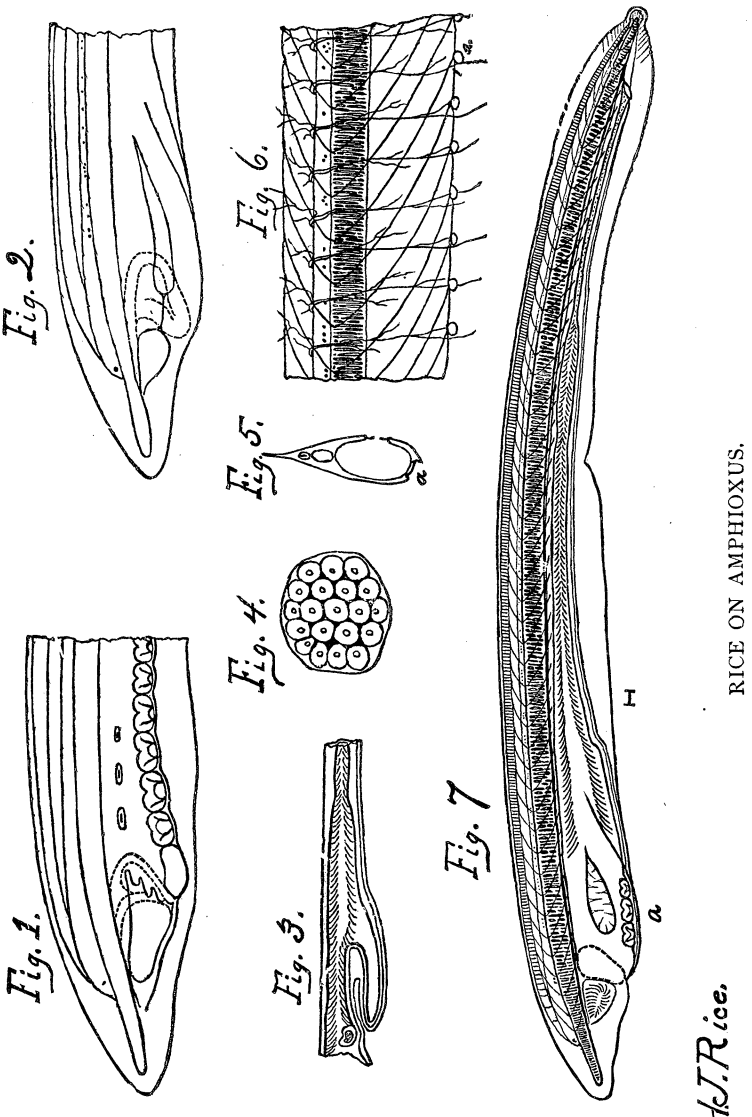
[*To be concluded.*]

PLATE I.



RICE ON AMPHIOXUS.

PLATE II.



RICE ON AMPHIOXUS.

EXPLANATION OF PLATE I.

The full length figures were drawn either from careful measurement of the parts of the animals, or with the assistance of a camera, so that the outlines may be considered as very nearly, if not quite, correct. Under each of these figures is a line representing the length of the individual.

FIG. 1.—Adult female, $1\frac{7}{16}$ths inches in length, seen from the left side. The egg-cases are represented as squarish blocks attached beneath the body-muscles within the limits of the branchium, which is almost fully expanded. The branchial clefts are shown as oblique lines crossing the anterior portion of the pharynx. In this figure the anal opening is represented about $\frac{1}{32}$ of an inch too far back, and, for want of space to make the lines clear and distinct throughout their entire length, the full number of muscle-plates at the ends of the body have not been indicated.

FIG. 2.—The cartilaginous pharyngeal ring with its tentacles and a portion of the branches of the mouth ring. The mouth ring shows the divisions of the branches into segments and the basal portion of the tentacular prolongations.

FIG. 3.—View of the right side of a portion of the pharynx, showing the extent and position of the saccular liver and the slender branches or bands which attach it to the bars of the branchial arches.

FIG. 4.—Three of the branchial arches of the left side, showing the central bars with their central division lines; the extent of the clefts in the length of each arch; the cilia lining the clefts; the triangular spaces, *a*, between the bases of the arches in which are formed the "branchial hearts" of the blood system, and the cross-bars, running from one side of the arches to the other, and acting as stiffeners to the cartilaginous framework.

FIG. 5.—Young animal, $\frac{3}{32}$ds of an inch in length. The mouth aperture is an eccentric opening upon the left side and partially surrounded by the forming tentacles. The branchial arches are large and prominent, and seven in number, and the liver cæcum is just forming from the central portion of the alimentary canal.

EXPLANATION OF PLATE II.

FIG. 1.—Left side of the anterior portion of the body of a young Amphioxus, showing the first six pharyngeal openings, the first three openings for the left branchial arches, and the mouth-cavity as it appears shortly after the cleft from the pharyngeal mouth aperture to the ciliated pit has closed. The peculiar shape of the anterior pharyngeal openings is caused by their position upon the right side of the median line of the pharynx.

FIG. 2.—An earlier stage of the same portion of the body shown in Fig. 1. Here the pharyngeal mouth aperture, the ciliated mouth cavity, and the cleft connecting the two are plainly indicated.

FIG. 3.—Portion of the alimentary canal of a young animal including the last branchial opening upon the left side of the pharynx, and the entire stomach cavity, and showing the forming liver diverticulum with the ventral blood vessel conforming to its lower border.

FIG. 4.—An egg capsule with its quota of ova, very much enlarged.

FIG. 5.—Diagrammatic cross-section of the body of a young Amphioxus. Section made through the pharyngeal mouth aperture and one of the pharyngeal clefts, as at *a*, Fig. 7, to show the connection of these openings with the central canal. The point upon the body wall or mouth welt, just to the right of the letter *a* in the figure, ought to be more sharply defined to represent one of the tooth-like processes of the mouth welt.

FIG. 6.—View of a portion of the muscular system of the left side of the body of an adult, showing the disk-like character of the notochord; the muscle-plates of the side muscles; the distribution of the nerves of the side, and the attachment and form of the generative bodies, *a*, at ordinary seasons.

FIG. 7.—Young animal, $\frac{5}{64}$ths of an inch in length, showing pharyngeal mouth opening with teeth; cartilaginous pear-shaped welt; ciliated pit, and the first three pharyngeal openings.